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HIGH SPIN ARMOR PIERCING WARHEADS DEVELOPMENT WITH MOLYBDENUM AND TANTALUM LINERS

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ABSTRACT

Exceptional high spin penetration performance is predicted from the computational design of improved high spin armor piercing warheads under the Objective Crew Served Weapon (OCSW) Program. A series of warheads were previously fabricated and tested using OCSW projectile dimensions. These warheads included 20 millimeter diameter high precision liners, 25 millimeter diameter heavy steel bodies and LX-14 high explosive charges. Experimental investigation included flash x-rays and penetration using a high spin testing apparatus designed specifically for the development of high spin armor piercing ammunition warheads. Several of the designs produced good penetration against rolled homogeneous armor (RHA). More recently, the CALE advanced arbitrary Lagrangian Eulerian (ALE) finite difference computer program was used to investigate and design armor piercing warheads using Mo and Ta liners with PAX-2A explosive charges. The objective of the redesign was to provide improved manufacturability, improved safety, and, if possible, increased performance characteristics. The liner materials were selected based on the previous high performance OCSW armor piercing results, including dynamic gun firing tests of prototype armor piercing ammunition. The two dimensional CALE includes spin and material failure, allowing the investigation of both design and spin rate on penetrator formation and radial dispersion. The computations predict the level of penetrator radial dispersion due to high spin, and detonation product impingement during penetrator formation. Computationally predicted reductions in penetrator radial dispersion and increased tip velocities were achieved through liner design considerations. Based on the computational results, a series of increased performance warheads fabrication and testing is currently planned using these newly improved OCSW warhead designs.

INTRODUCTION AND BACKGROUND

In designing an effective shaped charge liner, a high material density is desireable to maximize penetration [Chou 1986]. Molybdenum and tantalum are attractive materials for armor piercing ammunition warheads due to their high material densities (10.2 g/cc for molybdenum, 16.7 g/cc for tantalum) and demonstrated penetration performances [Schwartz 1998, Baker 1998, Baker 1996] in non-spin high performance anti-armor warheads. Copper, which is the traditional material for liners, has a nominal density of 8.9 g/cc, so molybdenum and tantalum would provide denser liners without compromising ductility. Even denser materials, like tungsten (19.2 g/cc), lack the necessary ductility, so the current research focuses on molybdenum and tantalum.

A common inhibitor to penetration in high spin conditions for armor piercing warhead development is radial dispersion of the jet after formation, where the jet loses cohesion under spin conditions (Fig. 1) [Nelson 1995, Weikert 1986, Jameson 1976]. This is a function not only of the design but also the liner material. Mass matching, where thicknesses are adjusted proportionately to compensate for density differences between materials, will not typically yield similar dispersion results from material to material, so designs must be material specific. Another problem is a phenomenon called the “gaseous guillotine”, where detonation products compressed by the shell casing are forced toward the central axis of the cartridge into the jet as it forms and cause discontinuities in the jet. The goal of simulation is to minimize shortcomings in design that would lead to fundamental performance flaws in fabrication.

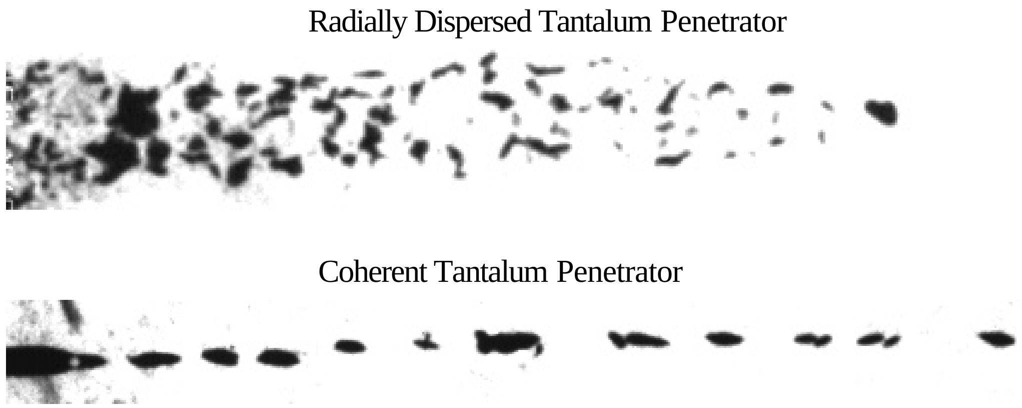

Figure 1. Flash x-ray results of a radially dispersed tantalum penetrator and a coherent tantalum penetrator under high spin conditions. (Baker, Cline, et al, 1998)

TACOM-ARDEC has a long history of anti-armor warheads design and fabrication under the Joint Service Small Arms Program (JSSAP), and current efforts focus on an upgrade to lightweight armor-piercing technology currently used in the small arms like Objective Crew Served Weapon (OCSW), the 30 mm M789, the LW30, and the M203 grenade. Successful testing in both the static spin chamber and through dynamic gunfire have been conducted for OCSW using copper, molybdenum, silver, and tantalum (Baker, Cline, et al, 1998). The focus of this project is the production of a more manufacturable, more IM compliant, and more penetrative warhead design that is still effective over engagement range and at necessary spin rates. The dimensions and configuration of the warhead are the same in all liner redesigns as the original OCSW configuration (Fig. 2).

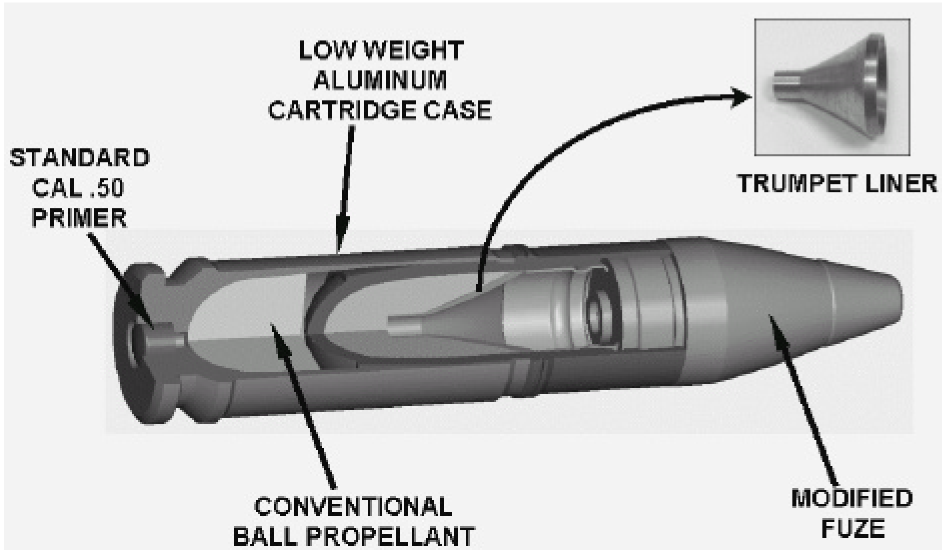

Figure 2. OCSW Armor Piercing Cartridge configuration

DESIGN METHOD

Copper, molybdenum, silver, and tantalum axisymmetric liners in warheads with base-initiated configuration have historically been the focus of investigation. With OCSW, a nose-fuzed configuration was established through a single design iteration, and the subsequent warheads were successfully tested both in a static spin chamber and dynamically with gun-launched testing. The current focus in shaped charge development is the improvement in liner manufacturability, performance, and safety.

The CALE [Tipton 1991] Arbitrary Lagrangian Eulerian (ALE) finite differencing computer program, which is used to create a two dimensional simulation of the performance of a warhead, includes spin and material failure, making it possible for the effects of both design and spin rate on radial dispersion (Fig. 3) and the gaseous guillotine (Fig. 4) to be analyzed.

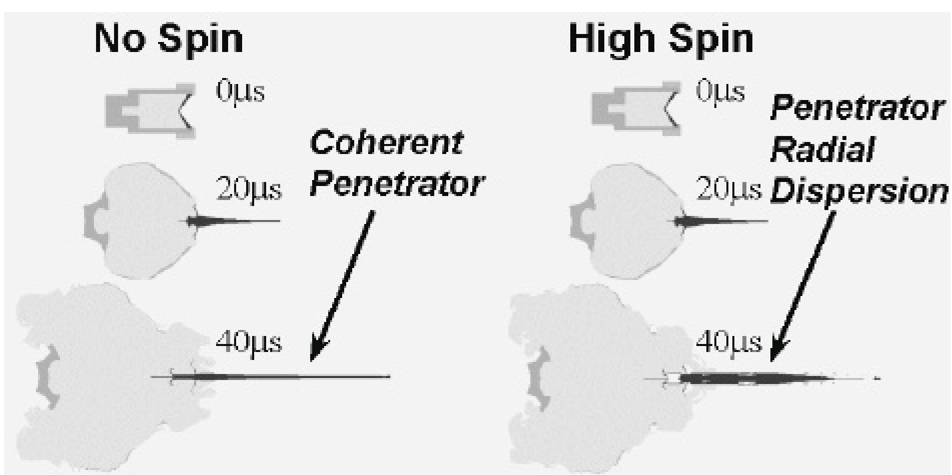

Figure 3. Example of CALE simulation with radial dispersion (Baker, Cline, et al, 1998)

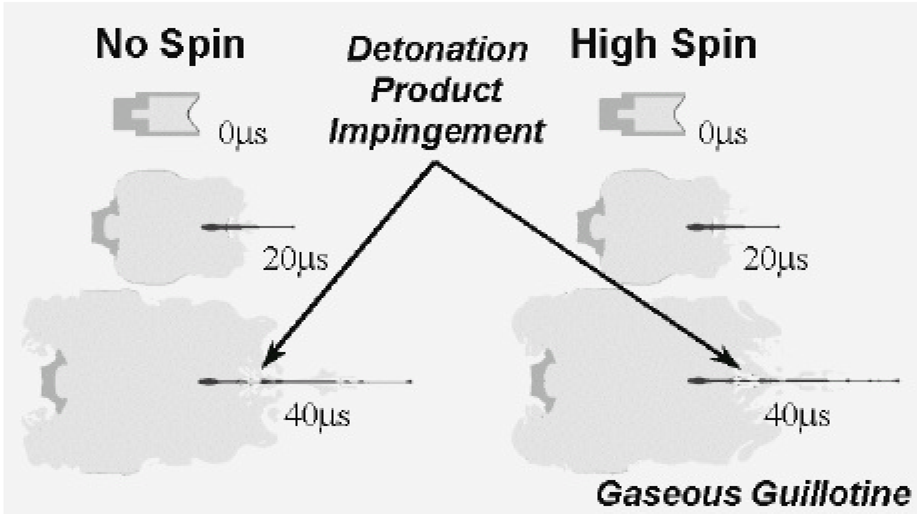

Figure 4. Example of CALE simulation with detonation product impingement (Baker, Cline, et al, 1998)

For this project, CALE was used to design armor piercing warheads with both molybdenum and tantalum liners. The basic warhead geometry was based on the OCSW projectile dimensions, with 20 millimeter diameter high precision liners and 25 millimeter diameter heavy steel bodies. PAX-2A explosive charges replaced LX-14, since PAX-2A is more insensitive munition (IM) compliant, making the round more safe for use in the field.

SIMULATION RESULTS

The original varied-thickness trumpet liner design was run in CALE with both LX-14 and PAX-2A, and a constant thickness design was generated through an iterative process to attain the best possible combination of tip velocity and cohesion for both molybdenum and tantalum with both types of explosive charge. Three slightly different designs yielded the best results for both types of explosive. A slower redesign with even greater stability and less radial dispersion, and a faster redesign with a greater tip velocity were generated. All three redesigns are predicted to outperform the baseline, with the faster redesign having the greatest penetration potential if it maintains coherence when tested (Fig. 5).

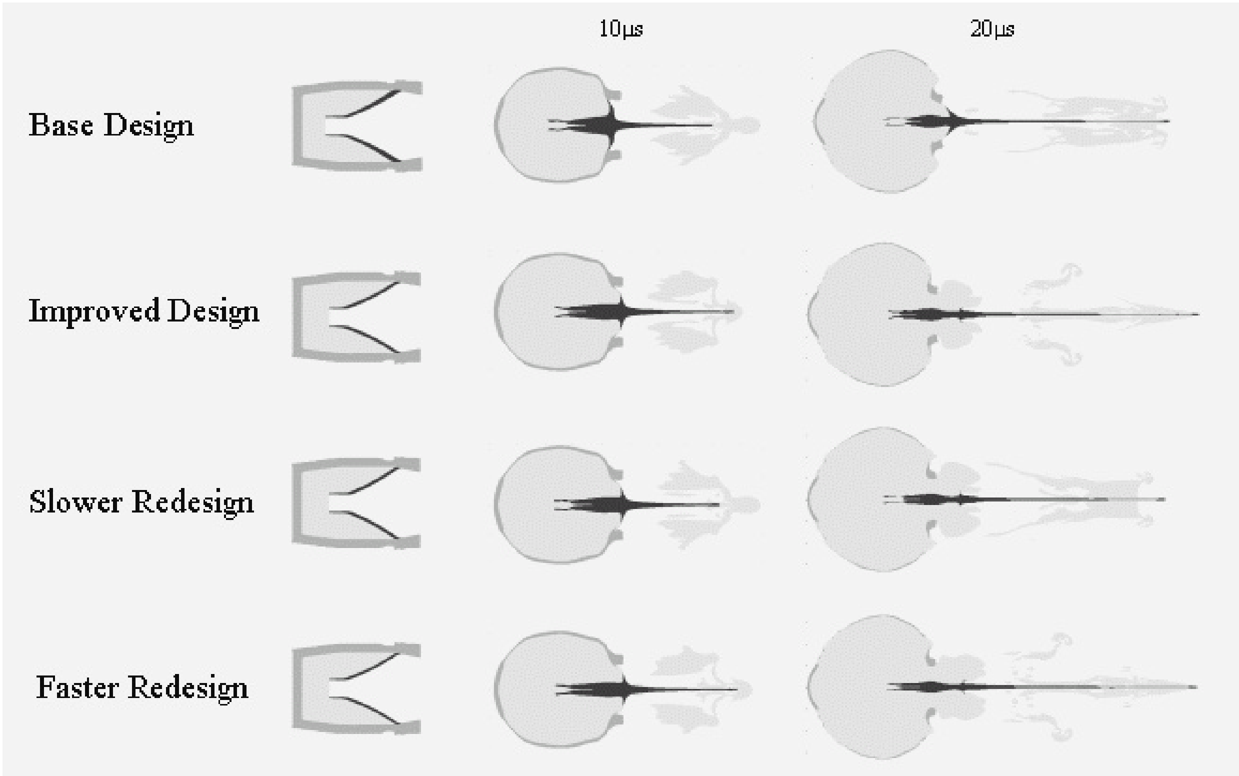

Figure 5. All three redesigns reach higher tip velocities. The slower redesign is more stable and slightly faster than the base, and the faster redesign is less stable but much faster than the base design.

A density profile further illustrates that the slower redesign should have more mass at higher velocities in the jet and have a tip velocity comparable to the base design. The mid-range redesign should yield comparable mass distribution in the jet, and the tip velocity should be significantly greater. The faster redesign has less uniform mass distribution in the jet than the other two redesigns, but if it avoids dispersion, its much higher tip velocity will result in greater penetration performance (Fig. 6).

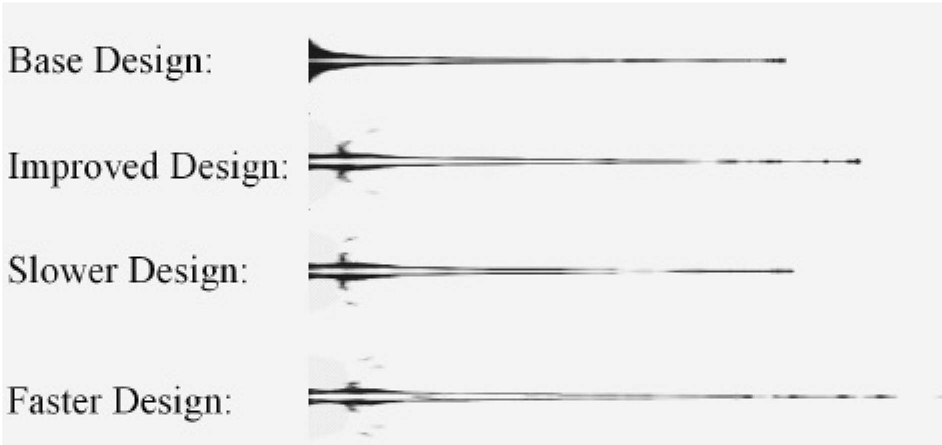

Figure 6. Density profile of the original and the three redesigns. The slower redesign has the most uniform density, while the faster redesign has the higher overall velocity. The mid-range design is the best attainable balance of speed and stability.

The accumulated mass distribution at given velocity further illustrates the predicted increase in performance of the redesigns. Each progressively faster redesign is predicted to have successively more mass moving at higher velocities in the jet, and all three are predicted to outperform the base design (Fig. 7). The faster redesign has the most mass distributed at the highest velocity with the greatest maximum velocity (the tip velocity). The slower redesign, while having the smallest tip velocity of the redesigns, still has a higher tip velocity than the original design while maintaining the smoothest mass distribution throughout the jet of all the designs.

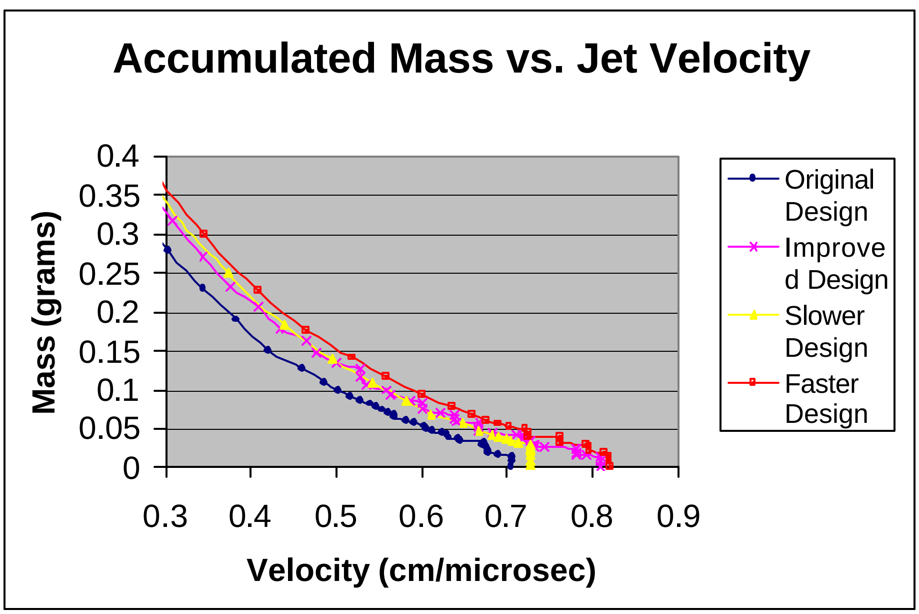

Figure 7. Accumulated mass as a function of velocity for the base design and the three redesign. All three redesigns have more mass at a higher speed in the jet than the original design.

CONCLUSIONS

The original nose fuzed OCSW AP warhead, after undergoing testing, was redesigned with the goal being to increase performance, manufacturability, and safety. A constant thickness redesign was generated and run in a two-dimensional CALE simulation, and is predicted to yield increased performance with a more IM compliant explosive (PAX-2A). Manufacturing methods are currently being investigated for production of redesigns using both molybdenum and tantalum.

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